

ADMINISTRATIVE INFORMATION

1. **Project Name:** SQA™: Surface Quality Assured Steel Bar Program
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5. **Date Project Initiated:** 01/01/2004
6. **Expected Completion Date:** 12/31/2007

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:**
The goal of this program is to develop and demonstrate an SQA™ prototype that enables efficient steel bar rolling process control of surface quality and is capable of automatic accurate-marking of the residual surface defects for downstream removal. The SQA™ technology has the potential to result in a 2.5% boost in the productivity of the target industries, generating significant savings in energy consumption and pollutant release.
8. **Technical Barrier(s) Being Addressed:**
The primary technical barriers are (1) the lack of a reliable surface defect detection system, (2) the complexity of the rolling process, and (3) the lack of a means for accurately registering and tracking surface defects in steel bars. Surface defects, given their sporadic nature, cannot be effectively addressed through sampling based process controls.
9. **Project Pathway:**
The project partners recognize that a systematic approach with advanced sensing and data analysis is required to effectively address the issues of surface quality associated with steel bars. The partners are working toward the objectives by developing:
 - Improved in-line surface defect detection capability with state-of-the-art signal processing algorithms and innovative bar speed measurement;
 - Integrated database systems that incorporate the mill operation data and the corresponding surface defect data;

- Advanced data pattern extraction models to establish the causal relationship for steel bar surface defects;
- New logistics for steel bar delivery to facilitate surface defect data exchange between the steel producers and their customers for residual defect removal by customers; and
- Intensive on-site test and refinement.

10. **Critical Technical Metrics:**

Baseline Metrics:

- False positive accuracy at ~20% in surface defect detection
- Smallest bar diameter at 8 mm (5/16"), limited due to severe vibration at smaller diameters
- Defect position registering accuracy at 2%, limited due to the bar rolling speed measurement accuracy
- Surface defect caused rejection rate at 5%

Project Metrics:

- False positive accuracy at 2%
- Smallest bar diameter at 5 mm (13/64", state-of-the-art rolling capability)
- Defect position registering accuracy at 0.02% (speed measurement accuracy)
- Surface defect caused rejection rate at 2.5%

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**

This new project is highly linked to a NICE³ project. Under the previous program, the project partners have successfully:

- Implemented a full-scale in-line surface defect detection system at a steel mill.
- Demonstrated and verified the detection capability of critical surface defects for hot rolled special quality steel bars.
- Demonstrated the beneficial impact of using the surface defect detection data to reduce scrap, energy consumption, waste and carbon equivalent emissions with defects that have simple forming mechanisms, such as roll cracks and overfills.
- Induced a commercial purchase of the in-line surface defect detection system from another steel mill.

Under the current ITP program, the project partners have:

- Improved the surface detection accuracy (false positive rate **from 20% to 5%**) of the in-line surface detection system.
- Completed the modal models for use in the design of vibration suppression.
- Completed the conceptual design of the speed measurement device.

12. **Future Plans:**

- Documented false positive rate down to 2% or less by 12/31/2004.
- Demonstrated capability of imaging and surface detection for wire (diameters smaller than 8 mm, or 5/16") rolling lines by 12/31/2004.
- Demonstration of 0.02% accuracy in speed measurement by 12/31/2005.
- Demonstration of off-line process diagnosis for rolling process faults that result in surface defects by 12/31/2005.
- Demonstration of near-real-time on-site process diagnosis for rolling process faults that result in surface defects by 12/31/2006.

- Demonstration of surface defect marking, tracking, and removal by the end user of the steel bars by 12/31/2006.
- Demonstration of 80% surface defect reduction (compared to the surface defect rates prior to this project) by 12/31/2007.

13. **Project Changes:**

The subcontractors in this project, University of Michigan (UM) and University of Wisconsin (UW), will not start their work until 06/01/2004 due to the awarding process. This could potentially delay the target date of delivering the 2% false positive rate. However, OGT is doing its best to make up for the lost time. OGT plans to bring in UM graduate student research assistants full-time at OGT's office during the 2004 summer months such that the OGT engineers and the UM RAs can work closely and effectively for the expedited development work.

14. **Commercialization Potential, Plans, and Activities:**

This SQA program to solve the major surface quality problems plaguing the US special quality steel bars and rods industry and their customers, the US forging industry, based on crosscutting sensors and controls technologies. Surface defects in steel formed in a hot rolling process are one of the most common quality issues faced by the American steel industry, accounting for roughly 50% of the rejects or 2.5% of the total shipment. Unlike other problems such as the mechanical properties of the steel product, most surface defects are sporadic and cannot be addressed based on sampling techniques. This issue hurts both the rolling and forging industry in their process efficiency and operational costs.

The SQA program is expected to result in a product that includes a HotEye™ surface inspection system, a sensor fusion system, and a rolling line monitoring station (with software). Side products in this SQA program are the vibration suppression mechanism and the speed measurement device.

For the US special quality bar rolling and forging industry alone, the SQA program, as documented in the proposal, has the potential to directly reduce their operational cost by 2.5%, or over \$200M per year and their energy consumption by 6 Trillion Btu per year. OGT expects to have a 35% market penetration by 2012. Technologies developed in this SQA program can also benefit other industries, such as steel sheet rolling and paper rolling, with similar processes, similar product geometry and similar surface quality requirement.

OGT has a very good chance of being the world's leading provider of the Surface Quality Assured Steel Bar technologies, if ITP continues to support this SQA project. OGT has established its footing in the primary target market based on the technology and product developed with the support from the NIST Advanced Technology Program and the ITP NICE³ program. Currently OGT is actively marketing its HotEye™ in-line surface inspection system and receiving positive responses from the industry.

However, inspection cannot improve quality. The potential customers are all looking into the process/quality control technologies, to be developed in this SQA program. This is why the majority of the domestic SBQ mills are supporting this SQA program. Without the support from the ITP, the development of the SQA technology and its associated benefits could diminish.

OGT is prepared to commercialize the SQA technology as soon as it is ready, through both direct sales and partnering, if possible. We have developed a domestic market penetrating strategy based on a goal of 35% penetration by 2012. It includes the pathway to the market, the build-up of the marketing, production and service workforce, and the potential sources for required financing, space, and equipment. OGT has established direct contacts with the potential domestic customers. In fact,

more than 80% domestic special quality bar producers and the largest US special quality bar buyers support participate in this SQA program.

In addition, OGT is reaching out to the global market based on the HotEye™ surface defect detection system. OGT has visited China Steel and Baoshang Steel. OGT is also invited to make presentations to Morgan Construction (US, on April 28th), SMS (Germany, May 14th) and Daniele (Italy, May 17th), the three largest rolling equipment suppliers to the steel industry around the globe. They are potential partners that can help OGT disseminate the technology and products, including those resulted from this SQA program, to steel mills worldwide.

15. Patents, Publications, Presentations:

Two Patents

“Optical Observation Device and Method for Observing Articles at Elevated Temperatures,” allowed in US (prior to this ITP program).

“An Apparatus and Method for Detecting Surface Defects on a Workpiece such as a Rolled/Drawn Metal Bar,” submitted for examination (prior to this ITP program).

One Publication

“Impacting Factor Identification of Surface Defects in Hot Rolling Processes Using Multi-Level Regression Analysis,” accepted by the *Transactions of the North American Manufacturing Research Institution of SME XXXII*, North Carolina State University, June 2004.

Three Presentations

“Real-time surface defect detection in hot rolling process,” The Iron and Steel Exposition and 2003 AISE Annual Convention, Pittsburgh, Pennsylvania, USA, September 28-October 1, 2003.

“In-line surface defect defection in special quality bars,” “The 25th US Forging Industry Association Technical Conference, Detroit, Michigan, USA, April 19-21, 2004.

“Imaging-based in-line surface defect inspection for bar rolling,” accepted by AISTech 2004 Iron & Steel Technology Conference and Exposition, Nashville, Tennessee, USA, September 15-17, 2004.